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Investigating the Efficacy of Optimization Structures Used In Adaptive Radiotherapy for SBRT Liver Cases

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ABSTRACT

Purpose: The Varian Ethos intelligent optimization engine (IOE2) automates the generation of non-overlapping optimization structures and resolves planning conflicts via a prioritized goal hierarchy. While designed to minimize manual intervention, the influence of user-defined structures on adaptive SBRT liver plan quality remains unclear. This study compares IOE-only adaptive plans against clinical and modified plans incorporating user-defined structures to evaluate effects on target coverage and organ-at-risk (OAR) sparing.

Methods: Twenty retrospective SBRT liver cases treated with Ethos were analyzed. Three adaptive plans were generated per case: (1) IOE-only (no manual structures), (2) the clinical adaptive plan, and (3) a modified plan using alternative user-defined structures (e.g., planning risk volume (PRV) expansions, or OARs cropped from the planning target volume (PTV) with 0.3 cm margins). All plans utilized identical prescriptions and VMAT/IMRT techniques consistent with the clinical plan. Goal priorities were adjusted in modified plans to test alternative strategies. Evaluation metrics included PTV coverage, OAR doses, total monitor units, homogeneity and conformity indices.

Results: IOE-only plans generally achieved adequate target coverage while sparing OARs, provided the highest-priority OAR topped the hierarchy. However, under competing objectives, target coverage was typically maintained by sacrificing lower priority OAR constraints. Plans using user-defined structures showed superior compliance across multiple OAR constraints without compromising target coverage. Early data suggest that PTV-derived structures with 0.3 cm cropping margins offer a more favorable balance between coverage and sparing than PRV-based approaches.

Conclusion: While Ethos IOE can generate adaptive SBRT liver plans without user-defined structures, supplemental user defined structures improve consistency when PTV and OAR objectives compete. PTV-derived structures improve target coverage and offer adequate OAR sparing compared to plans with PRVs.

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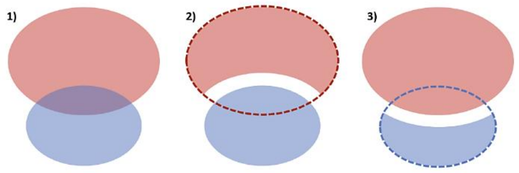
INTRODUCTION

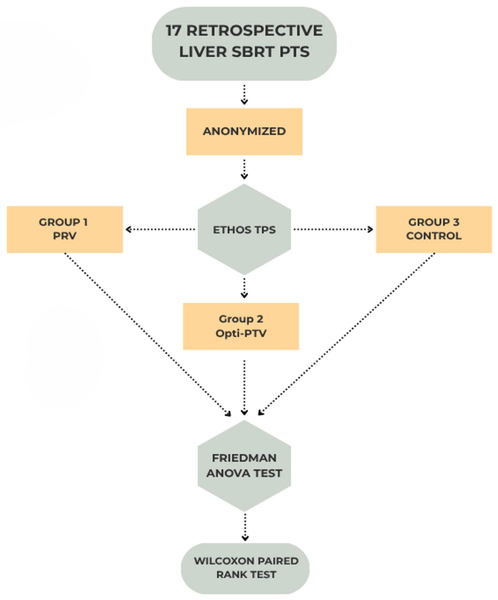
- Liver malignancies are associated with a historically poor prognosis. Radiation delivery is highly complex due to the close proximity of **organs at risk (OARs)**.
- **Online Adaptive Radiotherapy (oART)** addresses inter-fractional anatomical variations. Utilizing daily **cone-beam computed tomography (CBCT)**, **artificial intelligence (AI)** drives automated contouring and real-time plan optimization.
- The Varian Ethos therapy platform utilizes an **Intelligent Optimization Engine (IOE)** to enable rapid auto-segmentation and daily online plan generation.
- Traditional institutional workflows utilize **Planning Risk Volume (PRV)** margins around OARs to account for motion and setup uncertainties. However, in isotoxic treatment planning, these PRV margins frequently compromise target volume coverage.
- The IOE2 dynamically crops overlapping structures according to user-defined clinical priorities:



Red: Target, Blue: OAR

METHODS AND MATERIALS

20 retrospective Liver SBRT oART cases were replanned using 3 techniques:
Group 1: 3 mm PRVs created around the stomach, bowel, and duodenum.
Group 2: An optimization structure was created by subtracting the stomach, bowel, and duodenum from the PTV.
Group 3: Automatic ETHOS IOE2 without additional optimization structures.



RESULTS

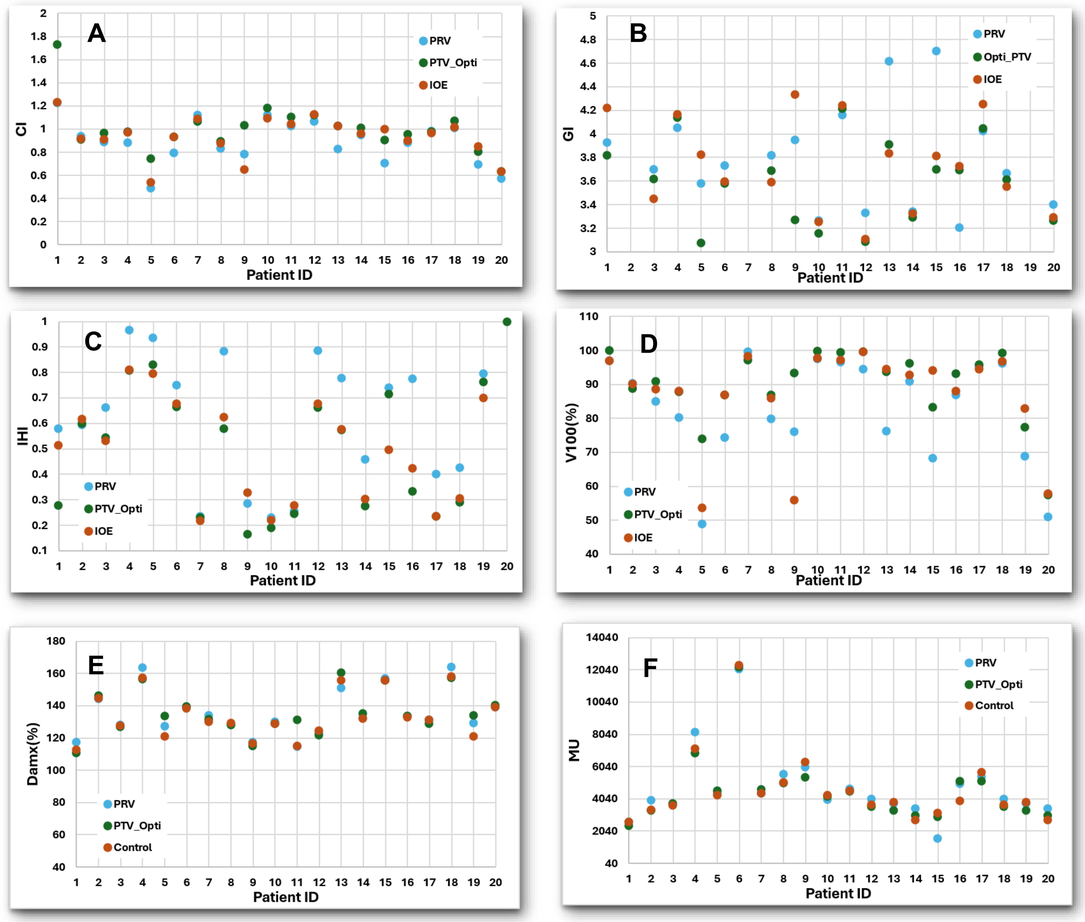


Figure 1. The plans were assessed by evaluating Conformity Index (CI) **(A)** , Gradient Index (GI) **(B)**, ICRU Homogeneity Index (HI) **(C)**, V100% target coverage **(D),** Body Dmax(%) **(E),** and Monitor Units (MU) **(F).**

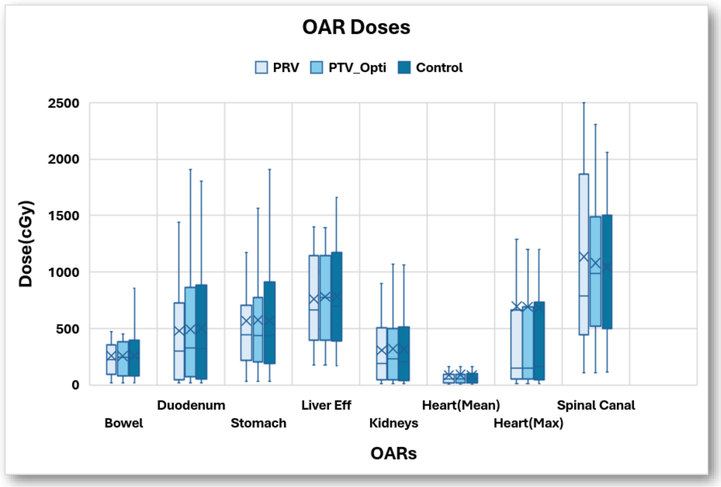


Figure 2. Box-and-whisker plot comparing OAR doses across the three different planning techniques.

Metric	P-Value	Significance
V100%	0.0002887	Yes
CI	0.001091	Yes
IHI	0.0000112	Yes
GI	0.03508	Yes
Heart Max	0.1653	No
Bowel Mean	0.441	No
Duodenum Mean	0.02029	Yes
Stomach Mean	0.3499	No
Max Spinal Canal	0.8607	No
Liver Effective	0.01925	Yes
Kidneys Mean	0.95	No
Body Max	0.2592	No
MU	0.522	No

Figure 3. Statistical significance ($p < 0.05$) of the evaluated metrics.

DISCUSSION & CONCLUSIONS

- This study evaluated and compared 3 distinct planning techniques.
- The findings suggest that PRVs reduced target coverage without providing superior OAR sparing over optimization structures.
- Relying solely on background IOE2 automation produced acceptable results in select cases; however, auxiliary helper structures further maximize target coverage and OAR sparing.
- While PRV margins offer conservative reassurance against interfractional motion during oART, their true clinical advantage remains questionable.
- Ongoing work uses post-treatment CBCTs to evaluate the dosimetric safety and geometric viability of PRV-free workflows.

REFERENCES

Varian Medical Systems. (2025). *Automated Planning in Ethos 2* (Publication ID: P1035867-330-C).